## UPDATING SCALING FACTORS FOR 10CFR PART 61

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### ABSTRACT

Part 61, Title 10 of the Code of Federal Regulations (10CFR61) has been in force since December 1983. Since then waste generators have been sending samples for offsite analyses (at a considerable cost) to better quantify the difficult-to-measure nuclides in their waste streams. In addition to the results obtained from the laboratories, many utilities have been relying on the results from previous work in this area including the Atomic Industrial Forum's report which was based on first principles and the Electric Power Research Institute's (EPRI) report which was based on operational data obtained from nuclear utilities. The utilities use these data to compare/contrast their actual results to those obtained industry wide.

The work caried out under the previous EPRI project assembled a database of approxiomately 700 waste stream data points gathered from samples analyzed: for the EPRI project, from a literature search, and also from the compliance programs of the utilities. From this data, a set of scaling factors were generated based on their relationship to one another and conclusions were drawn concerning the relative importance of these nuclides in the classification of waste under 10CFR61. Although the number of samples gathered and included under the EPRI project was significant, much of the data consisted of samples which contain the relevant (Part 61) nuclides at levels less than the lower limit of detection. For example, only 26 positive data points existed for Iodine-129 in Boiling Water Reactors (BWRs).

This paper presents results of the additional data gathered from the nuclear utilities. These data represents about five million dollars in analytical costs spent by the utilities in their compliance programs. The paper includes a statistical analyses of the raw data obtained to further conclusions previously developed and to realize new correlations. These new data will be of greater significance than the previous data as the data obtained from the utilities was specific to 10CFR Part 61 whereas most of the previous 700 data points obtained were from sources with little or no relationship to 10CFR61. In addition, the conclusions drawn from the previous work were extended to include these new data, and the data applied to determine actual generation rates of the 10CFR61 nuclides in lower-level waste.

Results from EPRI Project 1557-6 were published as NP4037, "Radionuclide Correlations in Low-Level Radwaste". It substantiates the methodology used by most power plants, scaling difficult to measure nuclides (i.e. nuclides which do not emit easily measured gamma rays) to those which are both easy to measure and possess similar chemical and physical properties. This methodology has been in use for several years in determining the transuranic content of waste based on the 144Ce concentration. The NRC has accepted this technique and has, in fact, suggested its extension to the problem nuclides listed in 10CFR61.

Through this initial project, a database of of 700 waste stream data points were gathered from several sources. Many of the samples reported in the EPRI report contained the relevant (Part 61) nuclides below the limit of defection. For example, only 26 positive data points existed for Iodine 129, and 29 data points for Tc-99 in BWRs.

### SCALING FACTOR METHODOLOGY

All utilities which generate low-level waste were contacted in order to collect as large a database as feasible. This combined database now represents approximately 1300 offsite analyses. From this database, scaling factors were determined and, where possible, generic scaling factors for use industry-wide have been proposed. The data requested under this new effort differed from that originally assembled in that the new data was specific to 10CFR61. The database amassed for this second study consists of 575 new sample analysis. The original scaling factors are presented along with the updated scaling factors in Table I. Important differences exist between BWRs and Pressurized Water Reactors (PWRs) which preclude the use of common scaling factors. In fact, important differences between substantially similar plant types may prevent generically categorized scaling factors from being used. As a result, the data presented in Table I is separated for both PWR and BWR data.

The scaling factors are presented as a log mean average (LMA) and log mean dispersion (LMD). Because of the large variability in data as a result of examining all PWR and BWR data concurrently, in some cases spanning 10 orders of *magnitude, the log* mean methodology results in a better overall prediction.

TABLE I

(Part 1)
10CFR61 Scaling Factors
Pressurized Water Reactors

| RATIO | PREVIOUS DATABASE COUNT | LMA | LMD | NEW DATABASE COUNT | LMA | LMD |
|---|---|---|---|---|---|---|
| C14/Co60 | 116 | 1.0E-2 | 18 | 353 | 1.2E-2 | 18 |
| Fe55/Co60 | NC | NC | NC | 291 | 8.9E-1 | 6 |
| Ni63/CO60 | 223 | 3.0E-1 | 6 | 370 | 3.7E-1 | 4 |
| Sr90/Cs137 | 196 | 5.0E-3 | 23 | 248 | 4.8E-3 | 15 |
| Tc99/Cs137 | 57 | 8.0E-4 | 37 | 97 | 7.8E-4 | 50 |
| I129/Cs137 | 56 | 2.0E-4 | 100 | 43 | 3.1E-4 | 104 |
| Pu239/Co60 | 383 | 1.0E-4 | 27 | 382 | 9.0E-5 | 21 |
| Pu239/Cs137 | 303 | 4.0E-4 | 50 | 288 | 2.0E-4 | 36 |
| Pu239/Ce144 | 190 | 3.0E-3 | 10 | 216 | 6.0E-3 | 7 |
| Pu238/Pu239 | 335 | 1.2E+0 | 3 | 375 | 9.8E-1 | 4 |
| Pu241/Pu239 | 182 | 1.3E+2 | 3 | 344 | 1.1E+2 | 3 |
| Am241/Pu239 | 316 | 6.0E+0 | 5 | 351 | 4.3E-1 | 4 |
| Cm242/Pu239 | 295 | 1.8E+0 | 7 | 324 | 8.1E-1 | 7 |
| Cm244/Pu239 | 298 | 5.0E-1 | 6 | 320 | 3.8E-1 | 7 |

NC = Not calculated
LMA = Log Mean Average
LMD = Log Mean Dispersion

TABLE I

(Part 2)
10CFR61 Scaling Factors
Boiling Water Reactors

| RATIO | PREVIOUS DATABASE COUNT | LMA | LMD | NEW DATABASE COUNT | LMA | LMD |
|---|---|---|---|---|---|---|
| C14/Co60 | 64 | 6.0E-4 | 16 | 94 | 7.1E-4 | 22 |
| Fe55/Co60 | NC | NC | NC | 80 | 4.1E-1 | 7 |
| Ni63/Co60 | 116 | 2.0E-2 | 5 | 116 | 2.0E-2 | 4 |
| Sr90/Cs137 | 124 | 1.0E-2 | 12 | 92 | 1.4E-2 | 9 |
| Tc99/Cs137 | 29 | 9.0E-5 | 27 | 57 | 3.4E-4 | 22 |
| I129/Cs137 | 26 | 7.0E-5 | 30 | 25 | 9.1E-5 | 9 |
| Pu239/Co60 | 235 | 5.0E-5 | 18 | 113 | 2.0E-5 | 7 |
| Pu239/Cs137 | 192 | 3.0E-4 | 28 | 91 | 1.5E-4 | 11 |
| Pu239/Ce144 | 105 | 5.0E-3 | 7 | 37 | 6.4E-3 | 35 |
| Pu238/Pu239 | 213 | 1.5E+0 | 3 | 110 | 1.7E+0 | 3 |
| Pu241/Pu239 | 98 | 1.1E+2 | 6 | 108 | 9.8E+1 | 3 |
| Am241/Pu239 | 194 | 7.0E-1 | 4 | 110 | 8.5E-1 | 3 |
| Cm242/Pu239 | 181 | 3.0E+0 | 6 | 100 | 6.5E+1 | 8 |
| Cm244/Pu239 | 180 | 6.0E-1 | 5 | 105 | 6.9E-1 | 4 |

NC = Not calculated
LMA = Log Mean Average
LMD = Log Mean Dispersion

Table II shows the distribution of new data within the 10CFR61 database. As shown, sample data collected are split 78:22 in favor of PWR data.

TABLE II

Distribution of Data Within the New 10CFR61 Database

| Sample Type | PWR | BWR | Total |
|---|---|---|---|
| All | 448 | 127 | 575 |
| Resin | 123 | 55 | 178 |
| Daw | 90 | 14 | 104 |
| RCS | 33 | 16 | 49 |
| Filter | 112 | 26 | 138 |
| Evap Btms | 18 | 11 | 29 |
| Low Activity | 161 | 25 | 186 |
| Medium Activity | 141 | 55 | 196 |
| High Activity | 119 | 47 | 166 |

Low Activity Co-60 Less than 0.01 uCi/unit
Medium Acitvity Co-60 between 0.01 and 1.0 uCi/unit
High Activity Co-60 greater than 1.0 uCi/unit

Tables III through VI show the various scaling factors and LMD's for the various sample breakdowns. A significant improvement in the LMD for certain scaling factors occurs when sample subsets are used. Furthermore, when selected data which are suspect are removed from the database, the database improves even further. Suspect data include Carbon 14 concentrations exceeding 1uCi/unit (8 Total). The revised scaling factors with selected data removed is presented in Table VII. The BWR scaling factors in Table VII show good fit of the data, with the exception of C-14 and Tc-99. All of the other applicable BWR scaling factors are within a factor of 10. While these results are not sufficient enough in themselves to claim a generic scaling factor for BWRs, it does provide a good bound in the data for utilities with BWR's. Computed scaling factors at BWRs should be reasonably close (within a factor of 10) to those listed. Anomalies to these data should be investigated on a case-by-case basis before inclusion into their Part 61 programs.

The selected PWR data presented in Table VII are not as promising in terms of the application of generic scaling factors. Iron 55, Nickel 63 and the transuranics are the only ratios with log mean dispersions less than 10. These results are similiar to those obtained with the old database.

Additional scaling factors were calculated for C-14, Tc-99, and I-129 by ratioing with Co60. These data along with other statistical data are presented in Table 8. Coefficients of determination for C-14 and Tc-99, improve as compared to Cs-137, but not by a significant amount (less than 15%).

GENERATION RATES OF 10CFR61 Nuclides

The generation rates of the 10CFR61 Nuclides in low-level waste were determined using EPRI Report NP-3370. This report details the radwaste generation rates from various waste streams at over 30 different plants. The year 1981, the latest for which detailed data were available, was selected. The average volume for each waste stream by plant type (BWR/PWR) were computed. The generation rates for the problem nuclides of C-14, Tc-99, and I-129 were computed by multiplying the nuclide concentration log mean average, specific to the plant type and waste stream, by the average volume. The results are shown in Table IX. A concentration factor of 1,000 was used for reactor coolant system resins (RCS) (primary resin) and RCS sludge.

CONCLUSION

Even though final analysis of the data is still being completed, some important initial conclusions have become apparent. Specifically, BWR scaling factors have improved significantly as compared to the old database. Clearly the data is improving as utilities are becoming more experienced in their sample collection. Furthermore, the laboratories have become more skilled in their analysis with the increased volume of samples they have received over the past year.

In addition to the generic Ni-63/Co-60 correlation discussed previously, generic scaling factors for BWRs may be considered based on these new data.

Finally, the inclusion of C-14, Tc-99, and I-129 on all manifests coupled with the uncertainties surrounding the estimation of these nuclides points out a discrepancy betwen reported and expected activity. The reported curies for Carbon-14 is about 100 times higher while Tc-99 and I-129 are about 10 times higher than what is expected by first principles. As a result of the concentrations received from the offsite laboratories, many utilities are overestimating the activity of these nuclides on their shipping papers. This may potentially affect the burial sites premature closure.

TABLE III

EPRI 10CFR61 New Data Base
Dry Active Waste Scaling Factors

| RATIO | BWR DATA COUNT | BWR DATA LMA | BWR DATA LMD | PWR DATA COUNT | PWR DATA LMA | PWR DATA LMD |
|---|---|---|---|---|---|---|
| C-14/Co-60 | 8 | 6.4E-04 | 22 | 73 | 1.6E-02 | 10 |
| Fe-55/Co-60 | 11 | 1.2E-00 | 4 | 54 | 2.9E-00 | 3 |
| Ni-63/Co-60 | 14 | 1.9E-02 | 3 | 77 | 4.8E-01 | 3 |
| Sr-90/Cs-137 | 9 | 2.6E-03 | 5 | 55 | 4.6E-03 | 14 |
| Tc-99/Cs-137 | 6 | 4.6E-04 | 10 | 26 | 8.8E-04 | 12 |
| I-129/Cs-137 | 3 | 2.6E-04 | 2 | 6 | 2.6E-03 | 178 |
| Pu-239/Co-60 | 13 | 7.0E-06 | 7 | 85 | 2.0E-04 | 17 |
| Pu-239/Cs-137 | 10 | 1.7E-04 | 7 | 65 | 4.0E-04 | 18 |
| Pu-239/Ce-144 | 3 | 4.5E-03 | 4 | 41 | 7.1E-03 | 6 |
| Pu-238/Pu-239 | 13 | 1.5E-00 | 1 | 81 | 1.0E-00 | 4 |
| Pu-241/Pu-239 | 12 | 1.1E+02 | 2 | 74 | 1.1E+02 | 3 |
| Am-241/Pu-239 | 13 | 9.1E-01 | 2 | 75 | 5.0E-01 | 4 |
| Cm-242/Pu-239 | 13 | 9.5E-01 | 5 | 66 | 5.1E-01 | 4 |
| Cm-244/Pu-239 | 13 | 7.2E-01 | 3 | 64 | 4.7E-01 | 15 |

TABLE IV

EPRI 10CFR61 New Data Base
(Evaporator Bottoms Scaling Factors)

| RATIO | BWR DATA COUNT | BWR DATA LMA | BWR DATA LMD | PWR DATA COUNT | PWR DATA LMA | PWR DATA LMD |
|---|---|---|---|---|---|---|
| C-14/Co-60 | 9 | 1.9E-04 | 7 | 18 | 2.8E-02 | 10 |
| Fe-55/Co-60 | 6 | 7.6E-02 | 30 | 16 | 1.5E-00 | 3 |
| Ni-63/Co-60 | 11 | 3.4E-02 | 5 | 18 | 7.8E-01 | 2 |
| Sr-90/CS-137 | 9 | 1.0E-02 | 6 | 12 | 6.8E-04 | 8 |
| Tc-88/Cs-137 | 5 | 2.0E-04 | 25 | 4 | 1.4E-02 | 655 |
| I-129/Cs-137 | 2 | 1.8E-04 | 5 | 2 | 5.0E-06 | 1 |
| Pu-239/Co-60 | 11 | 2.0E-05 | 7 | 15 | 2.3E-05 | 11 |
| Pu-239/Cs-137 | 9 | 1.2E-04 | 23 | 12 | 1.7E-05 | 8 |
| Pu-239/Ce-144 | 3 | 1.6E-01 | 7 | 8 | 5.2E-03 | 5 |
| Pu-238/Pu-239 | 11 | 2.3E-00 | 1 | 15 | 9.6E-01 | 2 |
| Pu-241/Pu-239 | 11 | 9.1E+01 | 3 | 13 | 9.9E+01 | 2 |
| Am-241/Pu-239 | 10 | 1.4E-00 | 2 | 15 | 7.4E-01 | 2 |
| Cm-242/Pu-239 | 8 | 2.4E-01 | 14 | 13 | 1.1E-00 | 3 |
| Cm-244/Pu-239 | 9 | 9.3E-01 | 7 | 13 | 5.2E-01 | 3 |

TABLE V

EPRI 10CFR61 New Data Base
(Resin Scaling Factors)

| RATIO | BWR DATA COUNT | BWR DATA LMA | BWR DATA LMD | PWR DATA COUNT | PWR DATA LMA | PWR DATA LMD |
|---|---|---|---|---|---|---|
| C-14/Co-60 | 50 | 6.2E-04 | 17 | 112 | 6.3E-03 | 19 |
| Fe-55/Co-60 | 40 | 3.4E-01 | 5 | 97 | 2.9E-01 | 6 |
| Ni-63/Co-60 | 55 | 2.4E-02 | 4 | 113 | 4.2E-01 | 4 |
| Sr-90/Cs-137 | 48 | 1.6E-02 | 12 | 89 | 4.5E-03 | 12 |
| Tc-99/Cs-137 | 28 | 9.3E-05 | 15 | 27 | 7.0E-05 | 45 |
| I-129/Cs-137 | 15 | 3.9E-05 | 10 | 18 | 1.1E-04 | 198 |
| Pu-239/Co-60 | 51 | 1.6E-05 | 5 | 115 | 3.1E-05 | 27 |
| Pu-239/Cs-137 | 48 | 7.9E-05 | 8 | 105 | 5.9E-05 | 25 |
| Pu-239/Ce-144 | 21 | 9.7E-03 | 4 | 74 | 5.7E-03 | 5 |
| Pu-283/Pu-239 | 50 | 1.7E-00 | 4 | 118 | 9.9E-01 | 3 |
| Pu-241/Pu-239 | 51 | 9.6E+01 | 3 | 111 | 1.1E+02 | 3 |
| Am-241/Pu-239 | 51 | 6.6E-01 | 3 | 113 | 3.7E-01 | 4 |
| Cm-242/Pu-239 | 48 | 9.7E-01 | 9 | 106 | 6.1E-01 | 6 |
| Cm-244/Pu-239 | 50 | 7.6E-01 | 4 | 107 | 3.0E-01 | 5 |

LMA = Log Mean Average
LMD = Log Mean Dispersion

TABLE VI

EPRI 10CFR61 New Data Base
(Filter Scaling Factors)

| RATIO | BWR DATA COUNT | BWR DATA LMA | BWR DATA LMD | PWR DATA COUNT | PWR DATA LMA | PWR DATA LMD |
|---|---|---|---|---|---|---|
| C-14/Co-60 | 14 | 2.0E-04 | 29 | 100 | 6.8E-03 | 16 |
| Fe-55/Co-60 | 12 | 2.1E-00 | 2 | 80 | 1.2E-00 | 5 |
| Ni-63/Co-60 | 24 | 1.5E-02 | 3 | 104 | 2.8E-01 | 5 |
| Sr-91/Cs-137 | 18 | 1.8E-02 | 3 | 55 | 1.0E-02 | 13 |
| Tc-99/Cs-137 | 13 | 2.1E-03 | 14 | 17 | 4.5E-03 | 23 |
| I-129/Cs-137 | 1 | 2.7E-04 | 1 | 9 | 1.4E-04 | 7 |
| Pu-239/Co-60 | 24 | 2.1E-05 | 5 | 104 | 9.5E-05 | 10 |
| Pu-239/Co-137 | 17 | 3.6E-04 | 8 | 60 | 1.4E-03 | 22 |
| Pu-239/Ce-144 | 9 | 8.7E-04 | 475 | 70 | 6.1E-03 | 9 |
| Pu-238/Pu-239 | 22 | 1.7E-00 | 2 | 102 | 8.8E-01 | 3 |
| Pu-241/Pu-239 | 23 | 9.1E+01 | 2 | 97 | 1.1E+02 | 2 |
| Am-241/Pu-239 | 23 | 1.7E-00 | 3 | 99 | 4.5E-01 | 3 |
| Cm-242/Pu-239 | 22 | 5.7E-01 | 3 | 95 | 1.2E-00 | 7 |
| Cm-244/Pu-239 | 21 | 7.8E-01 | 4 | 98 | 3.9E-01 | 5 |

TABLE VII

EPRI 10CFR61 New Data Base
(Selected Data Removed)

| RATIO | BWR DATA COUNT | BWR DATA LMA | BWR DATA LMD | PWR DATA COUNT | PWR DATA LMA | PWR DATA LMD |
|---|---|---|---|---|---|---|
| C14/Co60 | 94 | 7.1E-04 | 22 | 348 | 1.0E-02 | 15 |
| Fe55/Co60 | 80 | 4.1E-01 | 7 | 291 | 8.9E-01 | 6 |
| Ni63/Co60 | 116 | 2.0E-02 | 4 | 364 | 3.4E-01 | 4 |
| Sr90/Cs137 | 91 | 1.3E-02 | 8 | 245 | 4.4E-03 | 13 |
| Tc99/Cs137 | 53 | 2.1E-04 | 13 | 89 | 4.6E-04 | 38 |
| I129/Cs137 | 25 | 9.1E-05 | 9 | 38 | 1.6E-04 | 95 |
| Pu239/Co60 | 113 | 2.0E-05 | 7 | 379 | 8.5E-05 | 20 |
| Pu239/Cs137 | 91 | 1.5E-04 | 11 | 278 | 1.5E-04 | 30 |
| Pu239/Ce144 | 36 | 1.1E-02 | 5 | 216 | 6.0E-03 | 7 |
| Pu238/Pu239 | 109 | 1.8E+00 | 2 | 373 | 9.9E-01 | 3 |
| Pu241/Pu239 | 108 | 9.8E+01 | 3 | 344 | 1.1E+02 | 3 |
| Am241/Pu239 | 109 | 8.3E-01 | 3 | 346 | 4.2E-01 | 3 |
| Cm242/Pu239 | 100 | 6.5E-01 | 8 | 323 | 8.3E-01 | 6 |
| Cm244/Pu239 | 105 | 6.9E-01 | 4 | 318 | 3.7E-01 | 5 |

LMA = Log Mean Average
LMD = Log Mean Dispersion

TABLE VIII

Additional Comparisons Using
The New Data Base For PWRs

| RATIO | COUNT | LMA | LMD | R-SQUARED |
|---|---|---|---|---|
| C-14/Co60 | 353 | 1.2E-2 | 18 | .73 |
| C-14/Cs137 | 273 | 2.7E-2 | 14 | .71 |
| Tc-99/Co60 | 120 | 4.8E-4 | 51 | .59 |
| Tc-99/Cs137 | 97 | 7.7E-4 | 52 | .55 |
| I-129/Co60 | 58 | 9.8E-5 | 109 | .34 |
| I-129/Cs137 | 43 | 2.6E-4 | 118 | .19 |

TABLE IX

Radwaste Generation for Selected
Nuclides in Curies for 1981

| Nuclide | BWR Total Curies | PWR Total Curies |
|---|---|---|
| C-14 | 1.39 | 2.67 |
| Tc-99 | 0.23 | 0.06 |
| I-129 | 0.04 | 0.02 |